Week – 4 – September 14, 2013

NASA Aerosol (Particulate Matter) Products

Pawan Gupta
NASA ARSET- AQ On-line Short Course
Fall 2013

ARSET - AQ

Applied Remote SEnsing Training – Air Quality

A project of NASA Applied Sciences

Outline

- Remote sensing of aerosol - definitions
- Ground based remote sensing of aerosols – AERONET
- The NASA Satellite aerosol products.
- NASA aerosol remote sensing products as a surrogate for PM2.5

Aerosol Optical Depth

- AOD - Aerosol Optical Depth
- AOT - Aerosol Optical Thickness

These optical measurements of light extinction are used to represent aerosol amount in the entire column of the atmosphere.

Aerosol Optical Depth
vs
PM 2.5

AOD or AOT represents the total column loading of aerosols in the atmosphere

PM2.5 is a measure of the mass of particles in a specific size range near surface

Moderate AOD ~0.40
Near Mt. Abu, India

Photo courtesy of Brent Holben

Heavy AOD
Below the planetary boundary layer

Photo courtesy of Brent Holben

Visibility and PM2.5

Pictures taken from a same location at same time of day, on two different days

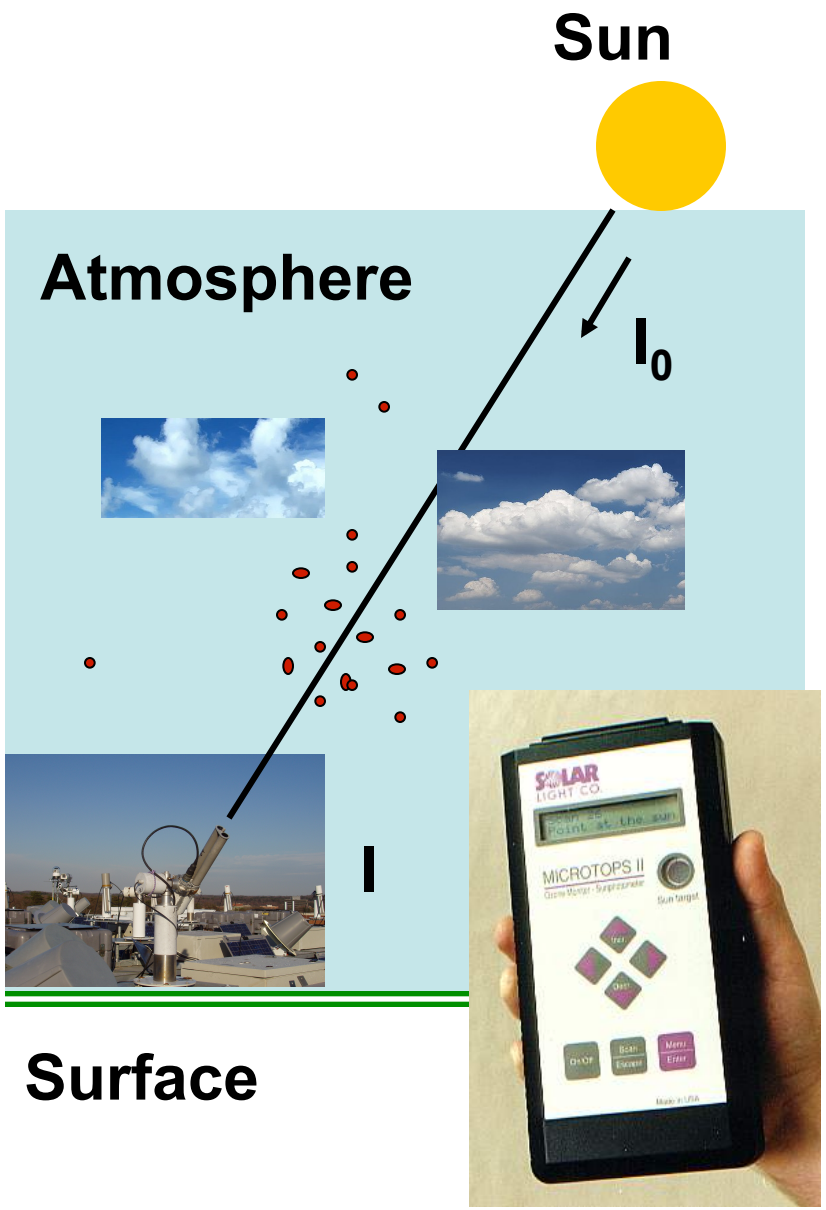
Aerosol Optical Depth

AOD is a unit less quantity

Sample AOD values:

	Equivalent PM2.5 mass concentration – Assuming 60 $\mu gm^{-3}/\tau$
0.02 - very clean isolated areas	~ 1 μgm^{-3}
0.2 – fairly clean urban area	~ 12 μgm^{-3}
0.4 – somewhat polluted urban area	~ 24 μgm^{-3}
0.6 – fairly polluted area	~ 36 μgm^{-3}
1.5 – heavy biomass burning or dust event	~ 90 μgm^{-3}

Optical Depth



The optical depth expresses the quantity of light removed from a beam by scattering or absorption during its path through a medium.

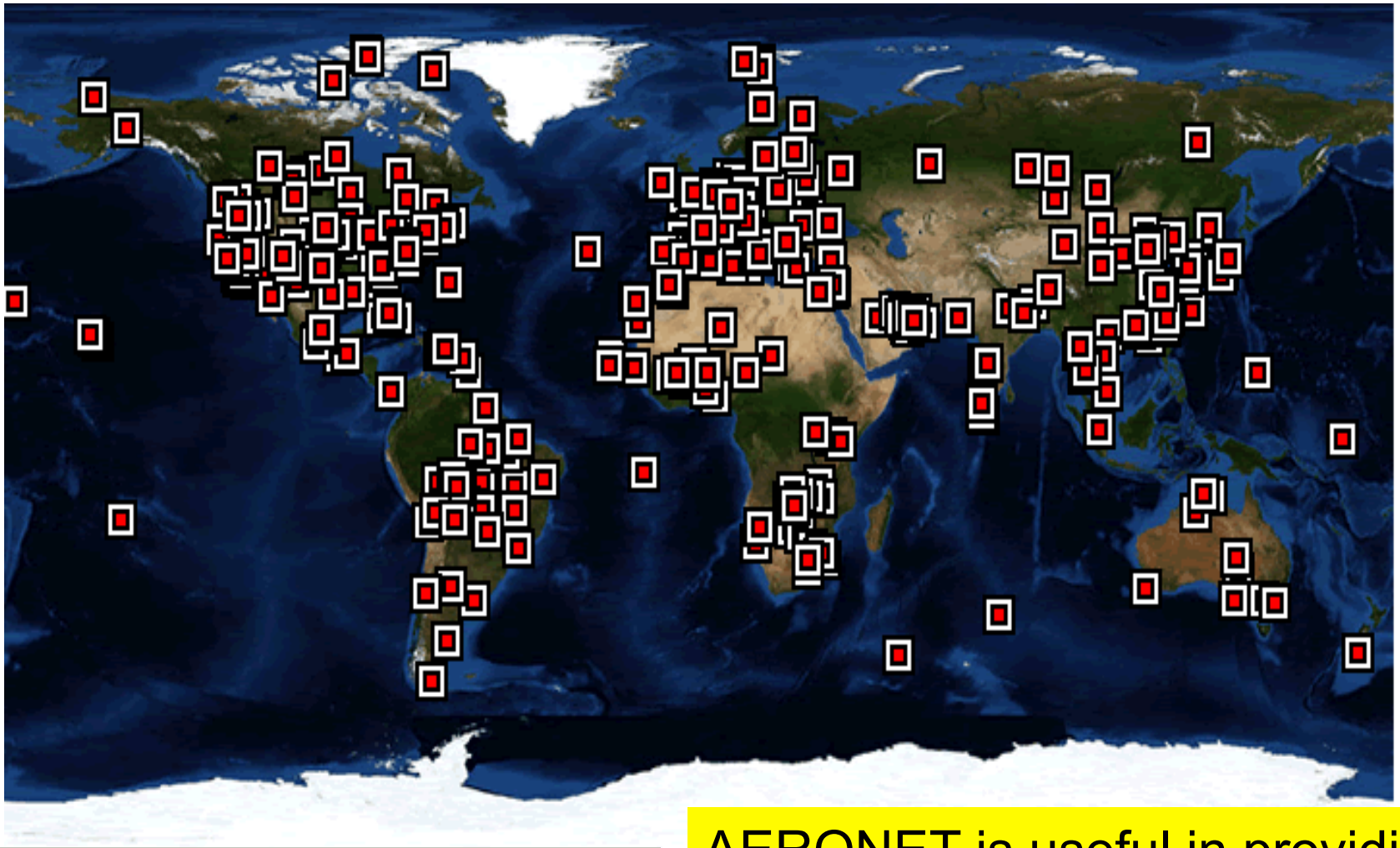
optical depth τ as

$$I = I_0 e^{-m\tau}$$

$$m = \sec\theta_0$$

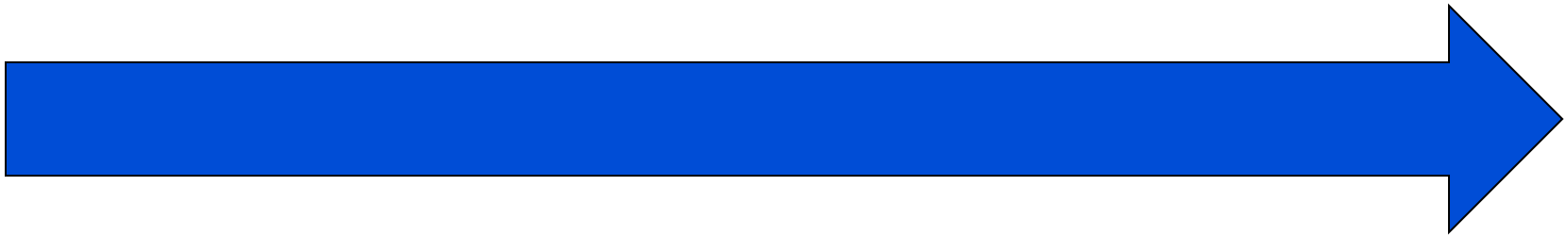
$$\tau = \tau_{Rayl} + \tau_{aer} + \tau_{ga}$$

AERONET



Aerosol Robotic Network
http://aeronet.gsfc.nas.gov

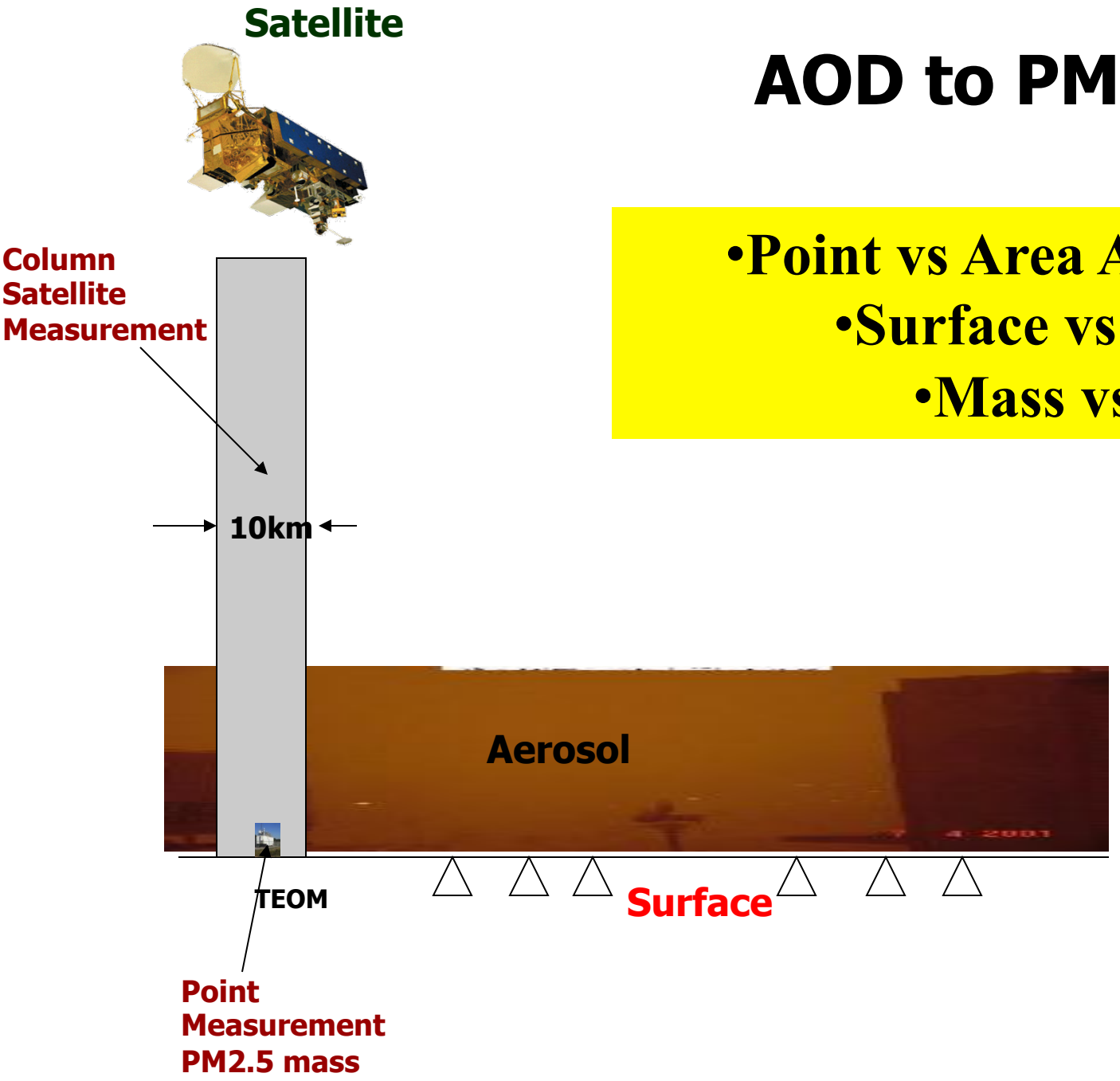
AERONET is useful in providing aerosol model information for satellite retrievals



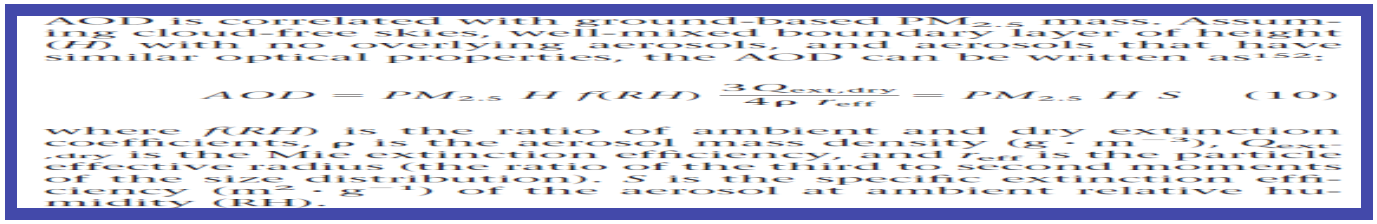
AOT to PM

AOD to PM

- Point vs Area Averaged
- Surface vs Column
- Mass vs Optical



AOD to PM2.5 - Theoretical



AOD is correlated with ground-based $PM_{2.5}$ mass. Assuming cloud-free skies, well-mixed boundary layer of height (H) with no overlying aerosols, and aerosols that have similar optical properties, the AOD can be written as[1,52]:

$$AOD = PM_{2.5}\, H\, f(RH)\, \frac{3 Q_{extdry}}{4 \rho\, r_{eff}} = PM_{2.5}\, H\, S \qquad (10)$$

where $f(RH)$ is the ratio of ambient and dry extinction coefficients, ρ is the aerosol mass density ($g \cdot m^{-3}$), Q_{ext} is the Mie extinction efficiency, and r_{eff} is the particle effective radius (the ratio of the third to second moments of the size distribution). S is the specific extinction efficiency ($m^2 \cdot g^{-1}$) of the aerosol at ambient relative humidity (RH).

- AOD – Aerosol Optical Depth
- H – Height of well-mixed boundary layer
- f(RH) – ratio of ambient and dry extinction coefficients
- p – aerosol mass density
- Q – Mie extinction efficiency
- r – particle effective radius
- PM2.5 – PM2.5 mass concentration

Hoff and Christopher, 2009

AOD-PM Relationship

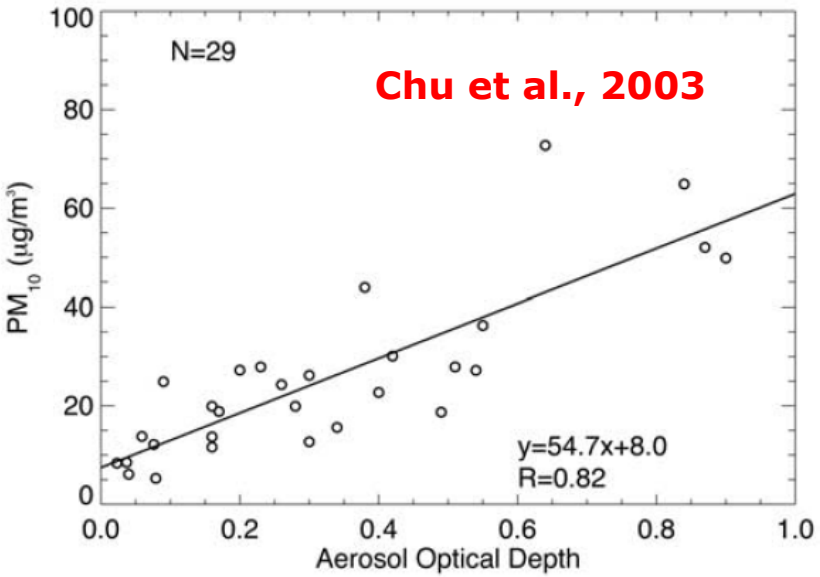
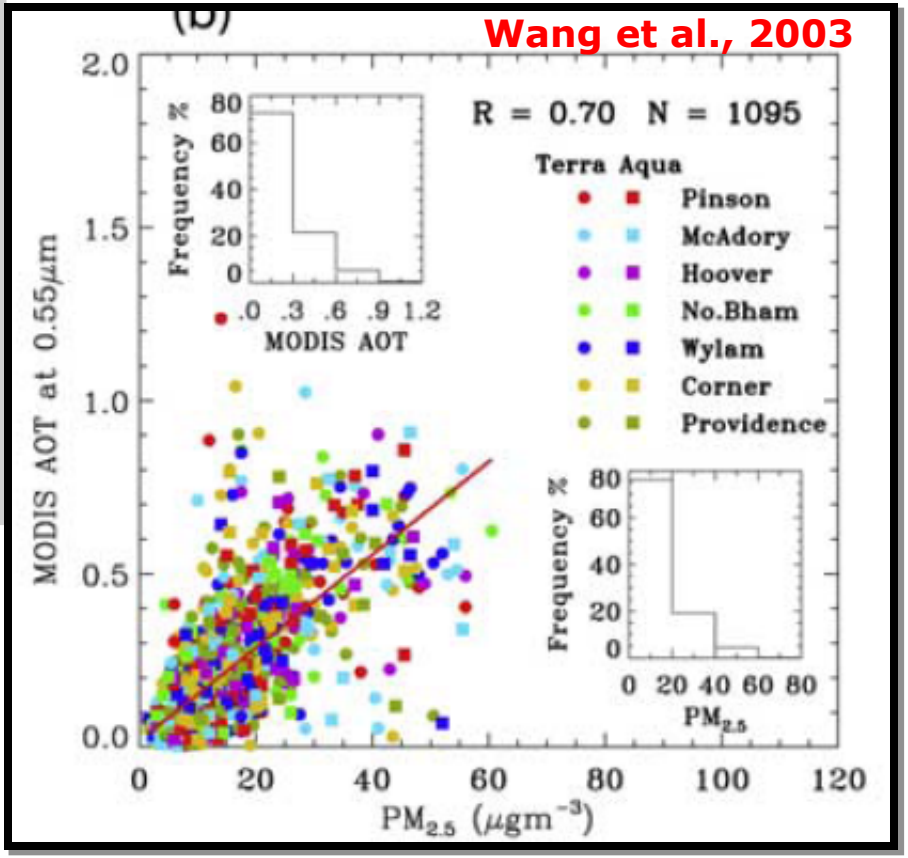
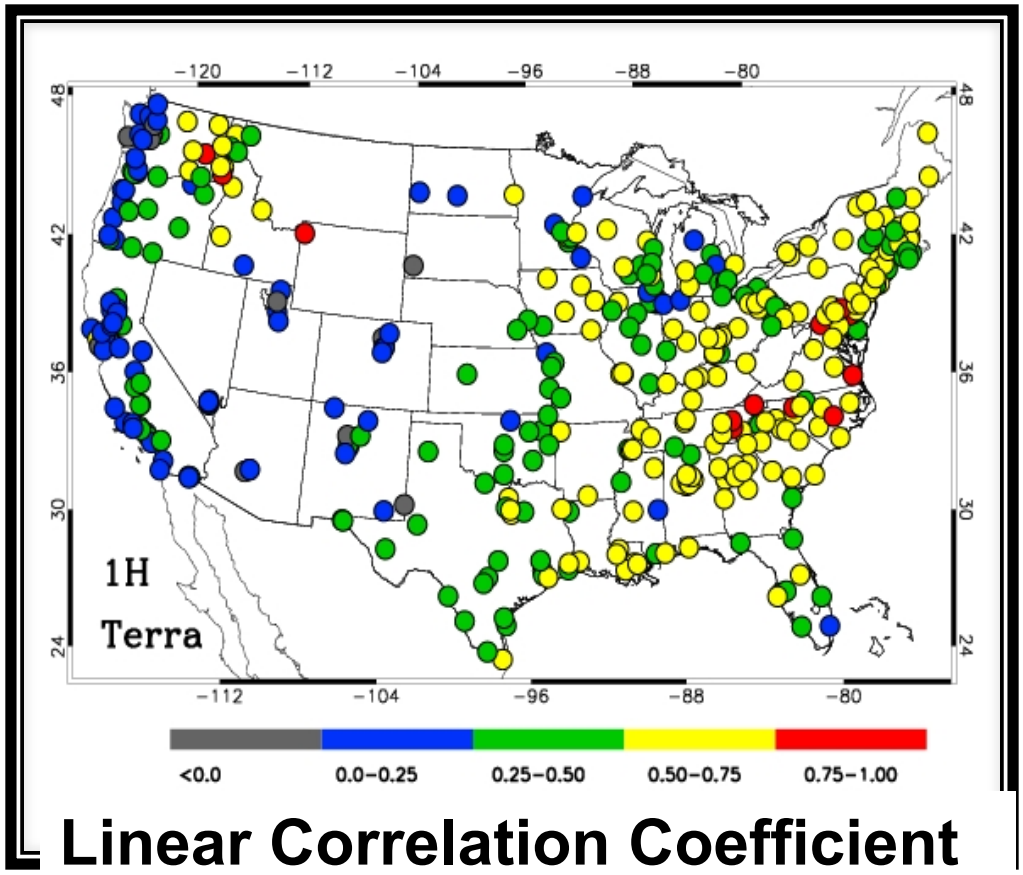


Figure 14. Relationship between 24-hour PM_{10} concentrations and daily averaged AERONET τ_a measurements from August to October 2000 in northern Italy.



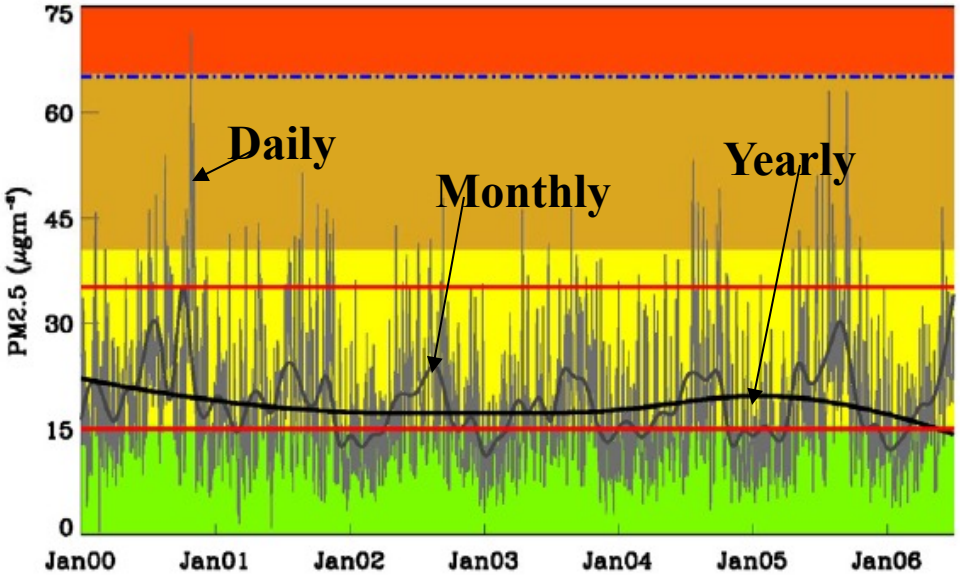
MODIS AOD/PM2.5 Correlations



Linear Correlation Coefficient

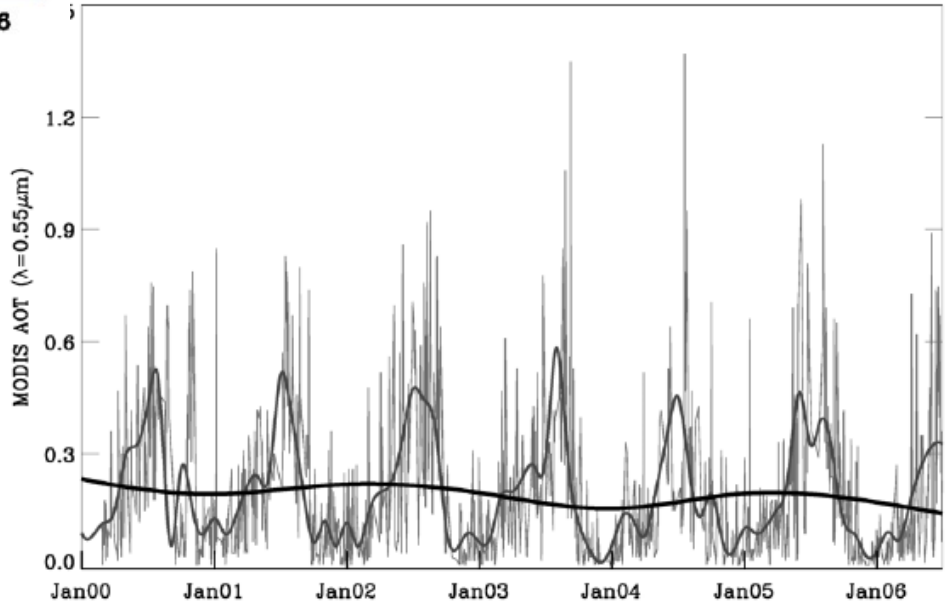
HOURLY CORRELATIONS BETWEEN TERRA MODIS AOD AND SURFACE PM2.5 VARY BY REGION

Potential Check --- Satellite vs Ground

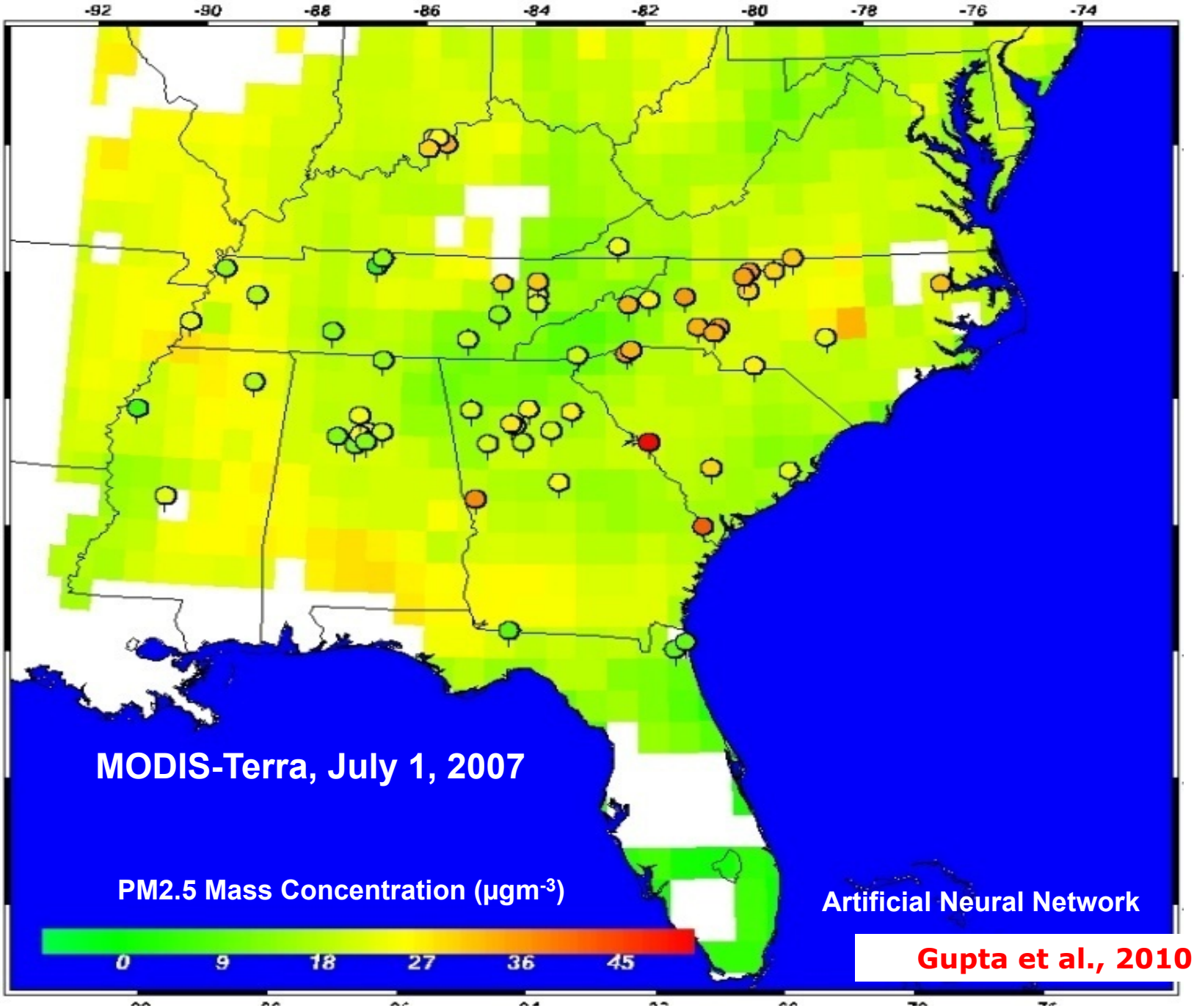


Satellite aerosol observations are able to see and follow the measurement trends at surface for air quality monitoring -

MODIS-Terra Collection 5, Level 2, 10 km² AOTs for 2000-2006, Birmingham, AL



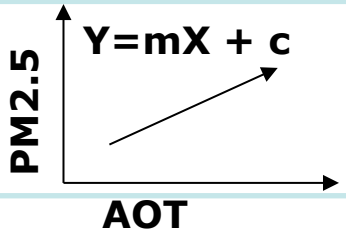
Gupta and Christopher, 2008


-92
-90
-88
-86
-84
-82
-80
-78
-76
-74
MODIS-Terra, July 1, 2007
PM2.5 Mass Concentration (μgm-3)
0
9
18
27
36
45
Artificial Neural Network
Gupta et al., 2010

PM2.5 Estimation: Popular Methods

Difficulty Level

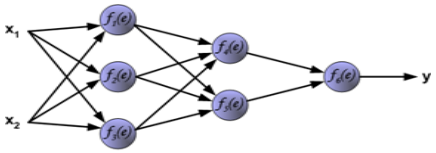
Two Variable Method



Multi-Variable Method

$$PM2.5 = \beta_0 + \alpha * \tau + \sum_{n=1}^{m} (\beta_n * M_n)$$

Artificial Neural Network



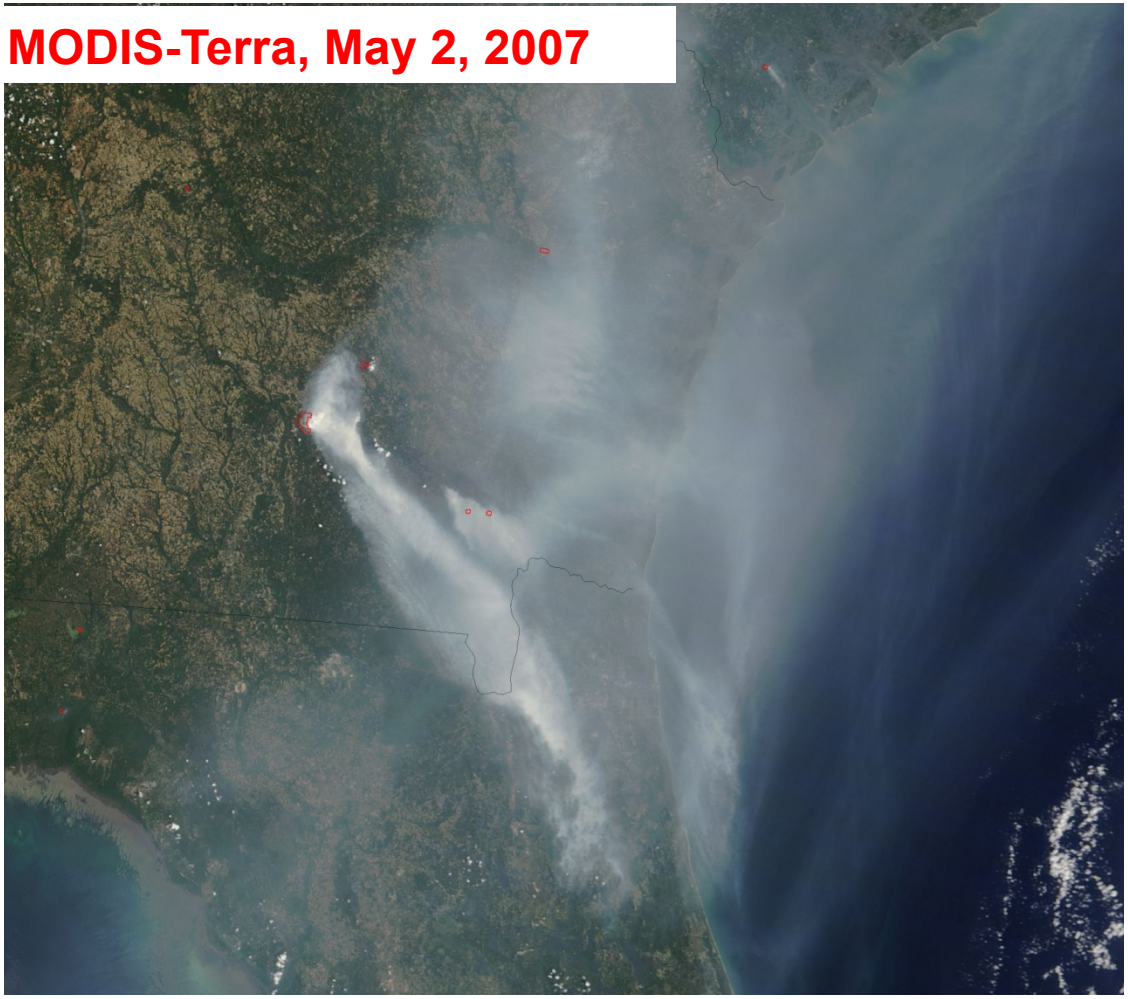
MSC

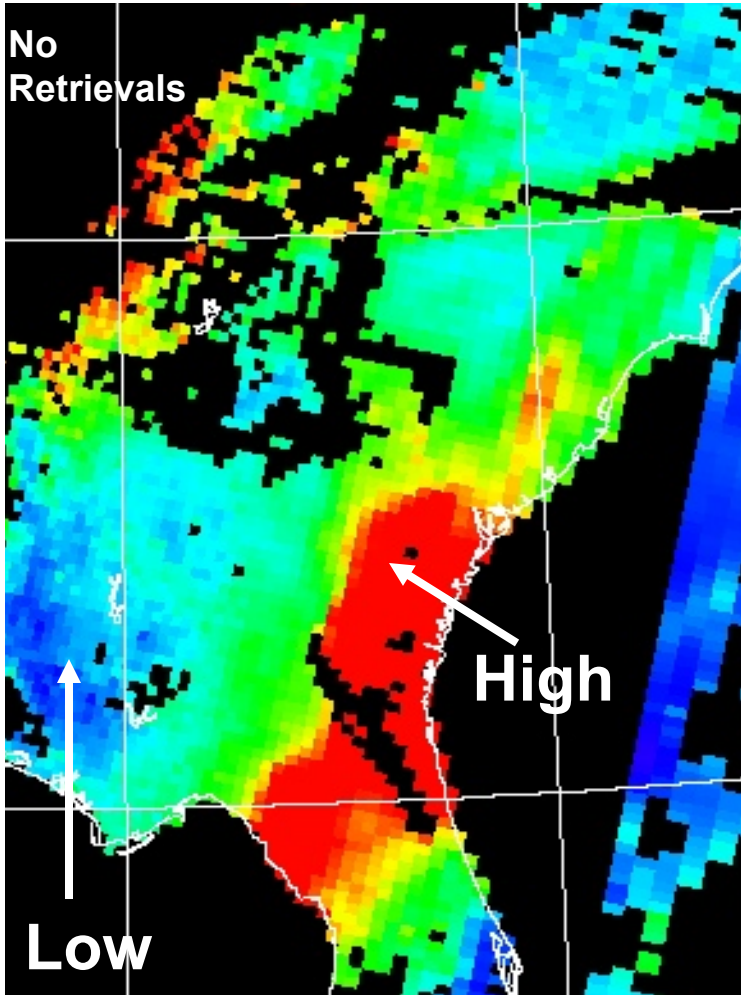
$$Estimated\ PM_{2.5} = \frac{Model\ surface\ aerosol\ concentration}{Model\ AOD} \times Retrieved\ AOD$$

and Empirical Methods, Data Assimilation etc. are under utilized

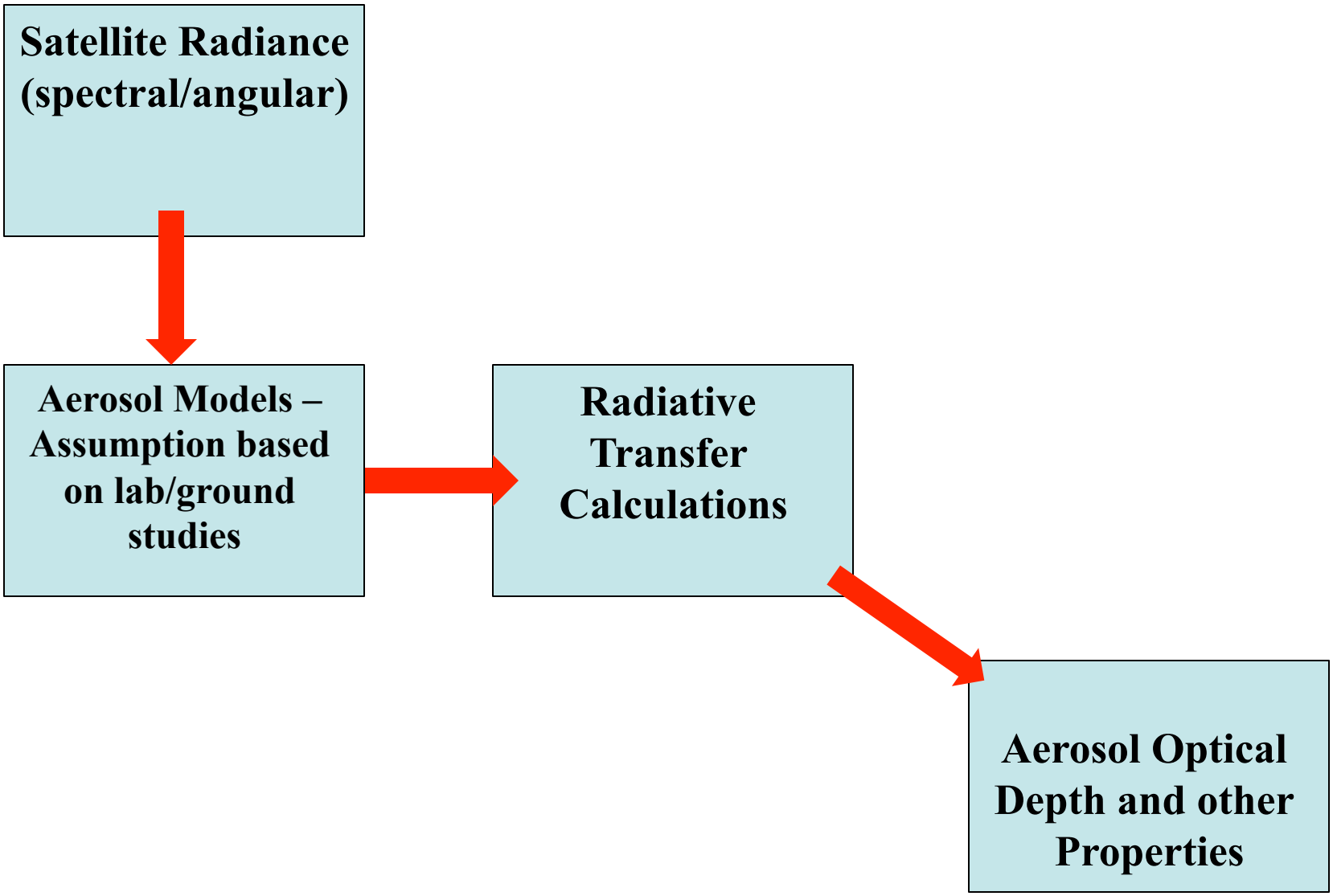
AOD from Satellite

Radiance -to- Aerosol Products





Aerosol Retrievals from Satellite Observations



Satellite Aerosol Products

InInI	MODIS	MISR	OMI	PARASOL
Strengths	Coverage Resolution Calibration Accuracy	Calibration Accuracy Particle shape Aerosol height for thick layer or plume	Indication of absorbing or scattering particles	Calibration Accuracy Particle shape*
Weaknesses	Bright Surfaces* Ocean glint Non-spherical particles	Coverage	Resolution Cloud contamination	Cloud contamination No coarse aerosol over land
Main Products	AOD Ocean - 5 wavelengths Land - 3 wavelengths Fine Fraction* *Ocean only	AOD 4 wavelengths Spherical/ Non-spherical ratio Particle Size (3 Bins)	AOD AAOD Aerosol Index	AOD over ocean Fine AOD over land Non-spherical fraction over ocean Angstrom exponent
Product Resolution (level 2 and at Nadir)	10 Km 3 Km (Collection 6)	17.6 Km	13 X 24 Km	20 Km
Product Levels	2	2	2	2
Global Level 3 Aggregates	Daily 8 Day 30 Day	Monthly 3 Month Annual	Daily Monthly	Monthly

Data Product Hierarchy

Level 1 Products – Raw data with and without applied calibration.

Level 2 Products – Geophysical Products (sometimes gridded)

Level 3 Products – Globally gridded geophysical products

MODIS Product Hierarchy

Level 1 Products

Radiance - 250m, 500m, 1km

Level 2 Products

Aerosol – 10km

Level 3 Products

Aerosol – 1 deg Daily/8day/Monthly

More User Control

Less User Control

Harder to Use

Easier to Use

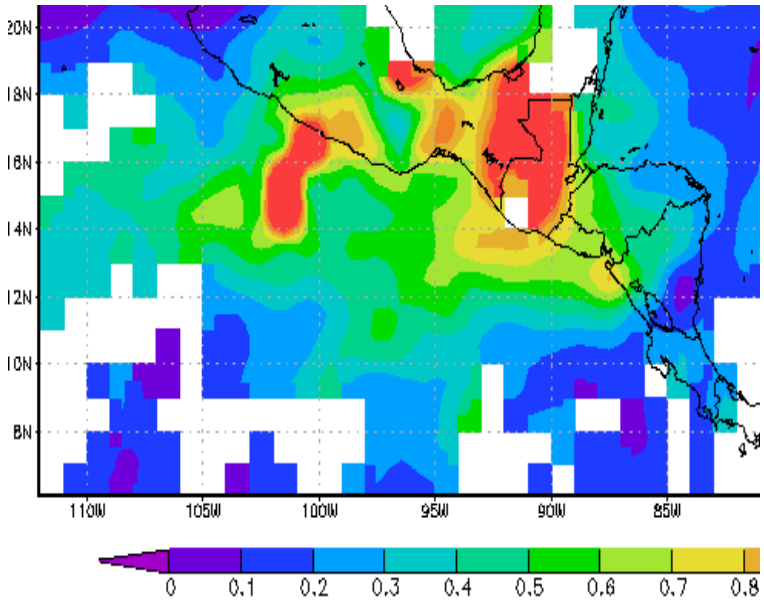
MODIS

MODIS: Aerosol Product

MOD04 or MYD04

10 km – instantaneous
01 deg – daily, weekly, monthly

May 10th, 2007



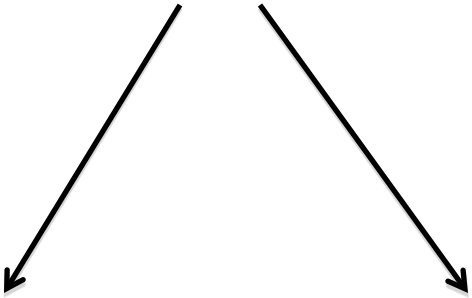
Smoke over Central America (Source: Giovanni)

- At least two daytime overpasses - Terra and Aqua
- Sensitive to Boundary Layer **Industrial, smoke & dust aerosols**
- Well validated over land

MODIS Aerosol Products

Three Separate Algorithms

Land **Ocean**



Dark Target (surface) – limited to only over dark vegetate surfaces

Deep Blue – Used over bright land surfaces

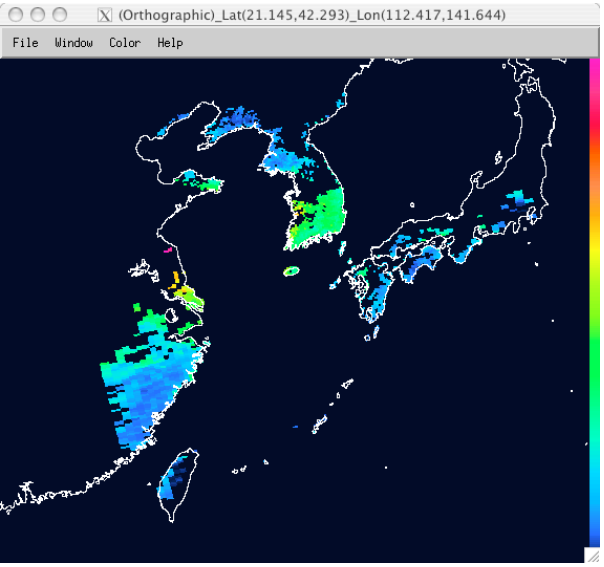
Detailed presentation on the MODIS ocean algorithm available at http://ARSET.gsfc.nasa.gov/materials

MODIS Aerosol Products

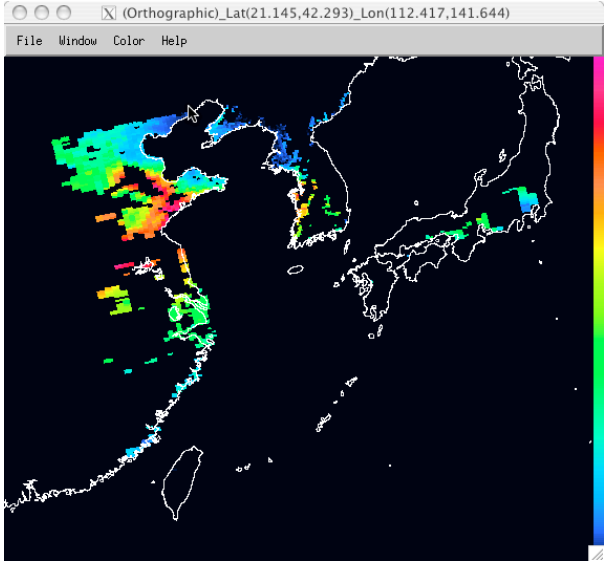
Three Separate Algorithms

Land

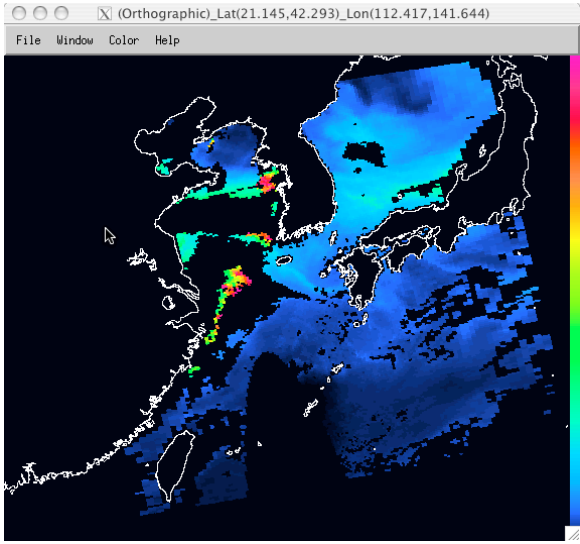
Dark Target



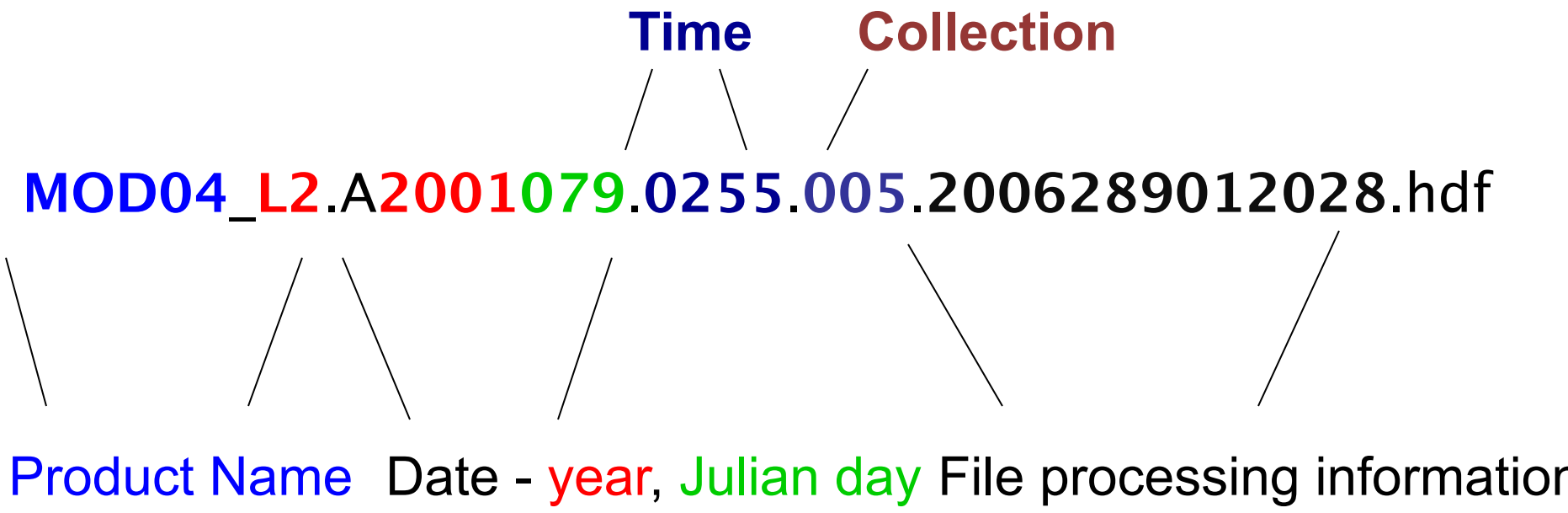
Deep Blue



Ocean



Understanding a MODIS File Name



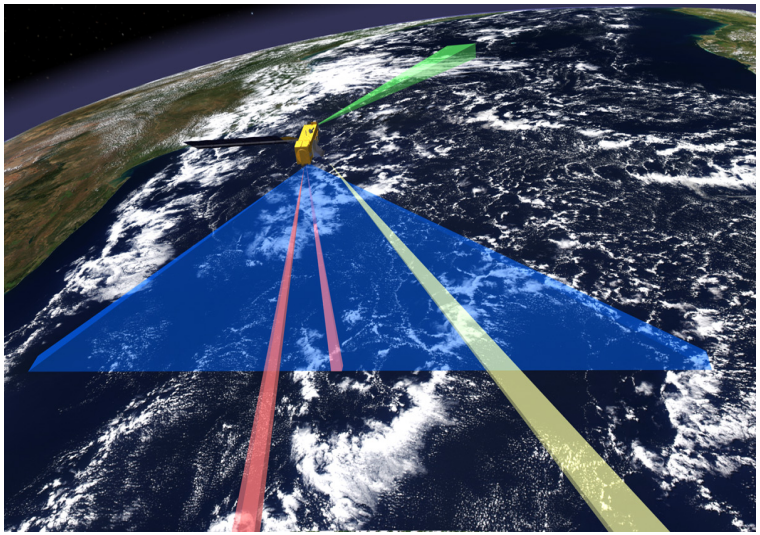
Access to MODIS Aerosol Products

- **NASA LAADSWEB. Searchable data base, FTP access**
  http://ladsweb.nascom.nasa.gov/index.html
- **MODIS-Atmos Site: Complete RGB archive and Level 3 product imagery.**
  http://modis-atmos.gsfc.nasa.gov/
- **Giovanni – web tool for imagery visualization and analysis**

  http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=MODIS_DAILY_L3

OMI

Ozone Monitoring Instrument (OMI)



One of four sensors on the EOS-Aura platform (OMI, MLS, TES, HIRDLS)

An international project:
Holland, USA, Finland
Launched on 07-15-04

Instrument Characteristics

-Nadir solar backscatter spectrometer

-Spectral range 270-500 nm (resolution~1nm)

-Spatial resolution: 13X24 km footprint

-Swath width: 2600 km (global daily coverage)

Retrieval Products

Column Amounts
-Ozone (O_3)
-Nitrogen Dioxide (NO_2)
-Sulfur Dioxide: (SO_2)
-Others

Aerosols

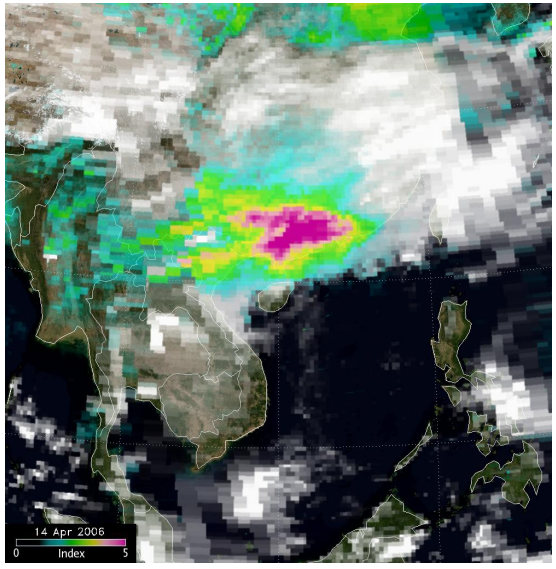
Applications of the Aerosol Index

-Validation tool for transport models

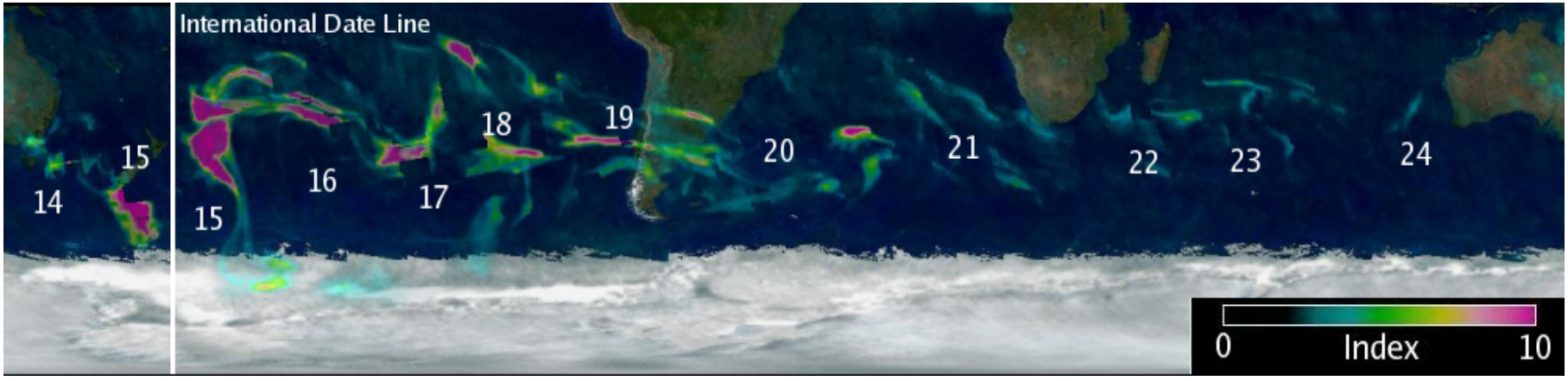
-Separation of carbonaceous from sulfate aerosols

-Identification of aerosols above PBL (i.e., PBL aerosols are not detectable by AI)

-Tracking of aerosol plumes above clouds and over ice/snow



Aerosol s over clouds:
April 14, 2006



Transport around the globe of a high altitude smoke layer generated by the Australian fires in December 2006. Numbers indicate the day of the month.

OMI data site

http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI

Version 003 OMI Level 2, Level 2G, Level-3 and Climatology Products			
Short Name & Data Access			Product Description
Level-2 Orbital Swath (Nadir pixels 13x24 km)	Level-2G Global Binned (0.25x0.25 or 0.125x0.125 deg)	Level-3 Global Gridded (0.25x0.25 or 1x1 deg)	
Aerosols			
OMAERUV	OMAERUVG	OMAERUVd	OMI/Aura Near-UV Aerosol Optical Depth and single Scattering Albedo
OMAERO	OMAEROG	OMAEROe	OMI/Aura Multi-Wavelength Aerosol Optical Depth and single Scattering Albedo

OMI-Aura_L2-OMAERUV_2011m1024t0521-o38692_v003-2011m1024t115317.he5

Product name

YYYYmMMDDtHHMM

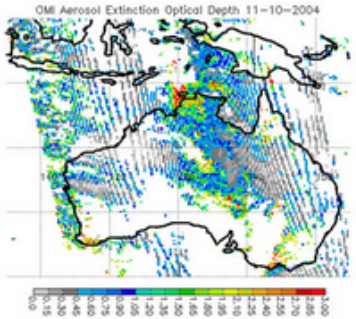
Aura OMI Near-UV Aerosol Data Product-OMAERUV (V003)

NEWS: Please read the important information related to OMI Anomaly

Data Access

• Mirador - fast search & download

OMI Aerosol Optical Depth



Principal Investigator (P.I)
Omar Torres
(NASA GSFC)

Data Version and Data Holdings

Processing	Version	Begin Date	End Date
Forward	003	Oct 1, 2004	Current

Production Frequency: 14 files/day
Granule (File) Coverage: one orbit
File Size(Approx): 6 MB

OMAERUV

Platform: EOS-Aura
Instrument: OMI

Product: Level-2 OMI Near-UV Aerosol Optical Depth- OMAERUV (V003)

Data Set Short Name: OMAERUV

Data Set Long Name: OMI/Aura Near UV Aerosol Optical Depth and Single Scattering Albedo1-orbit L2 Swath 13x24 km (v003)

OMI Data Documents
-Short Data Guide from GES DISC

-ReadMe, Data Quality and Release Spec Information for OMAERUV (from Algorithm Lead)

-File Format Specification

-Data Read Software & Tools

- Giovanni: Data Exploration Interface

- OMI Data User's Guide

OMI Algorithm Documents

- Algorithm Theoretical Basis Document

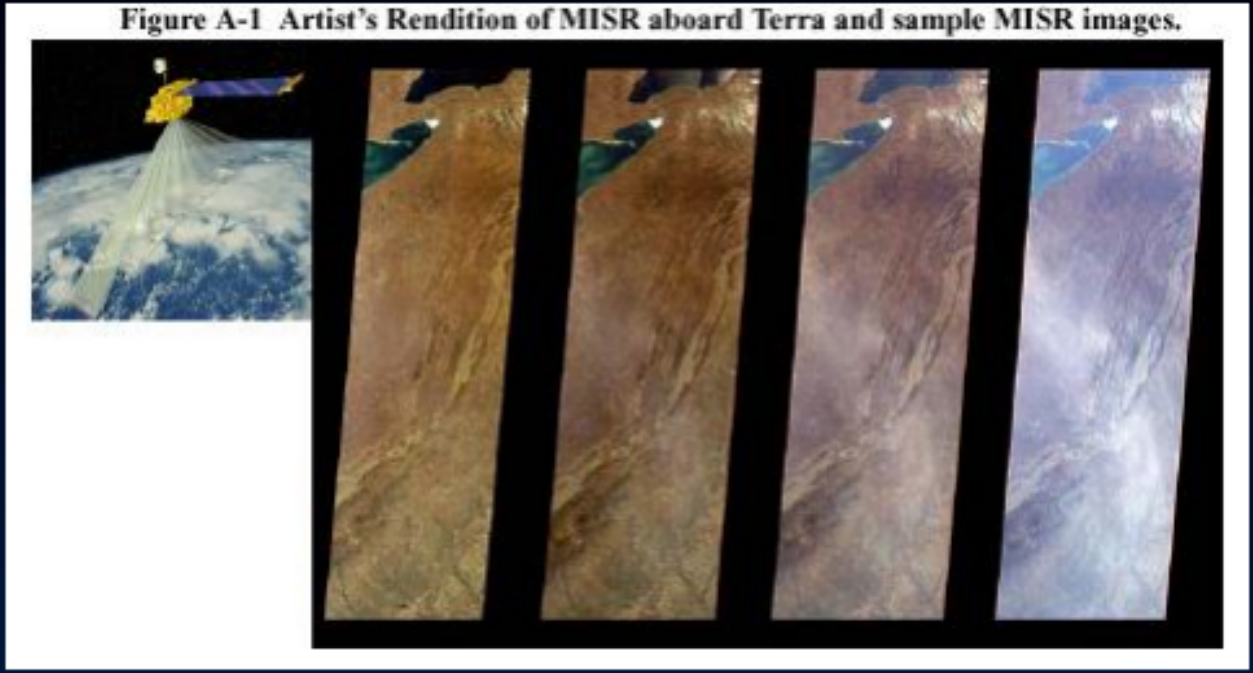
Other Related Documents:

-OMAERUV Document for Global Change Master Directory
- HDF-EOS Aura File Format Guidelines

Other Links :
EOS-Aura OMI Page
OMI Home Page (KNMI-Netherland)
OMI/TOMS Home Page (GSFC-NASA)
Atmospheric Chemistry & Dynamics Page
Aura Validation Data Center (AVDC)

MISR

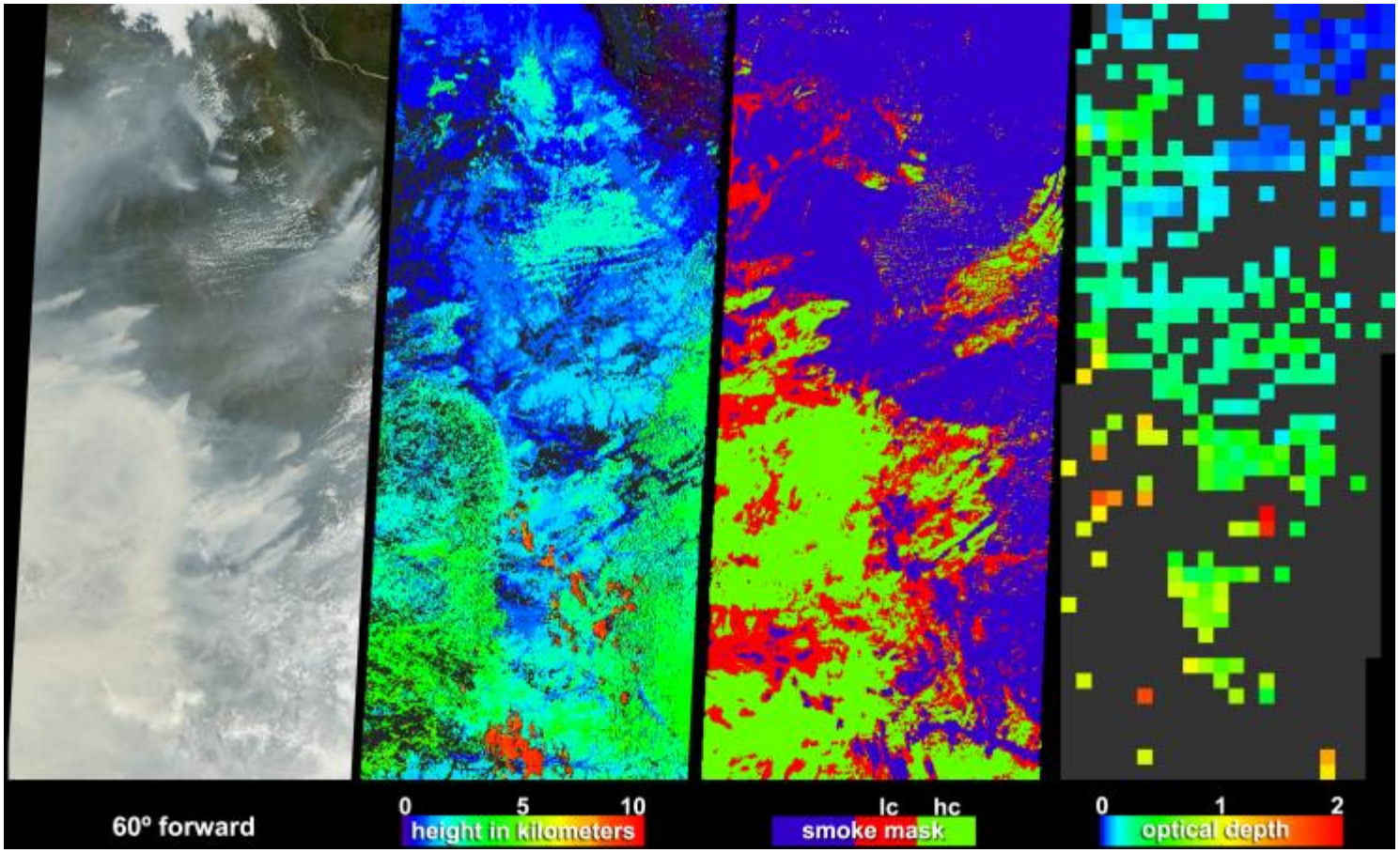
MISR Background



Four MISR images over Appalachain Mountains
Nadir, 45.6 deg, 60.0 deg, 70.5 deg forward viewing cameras

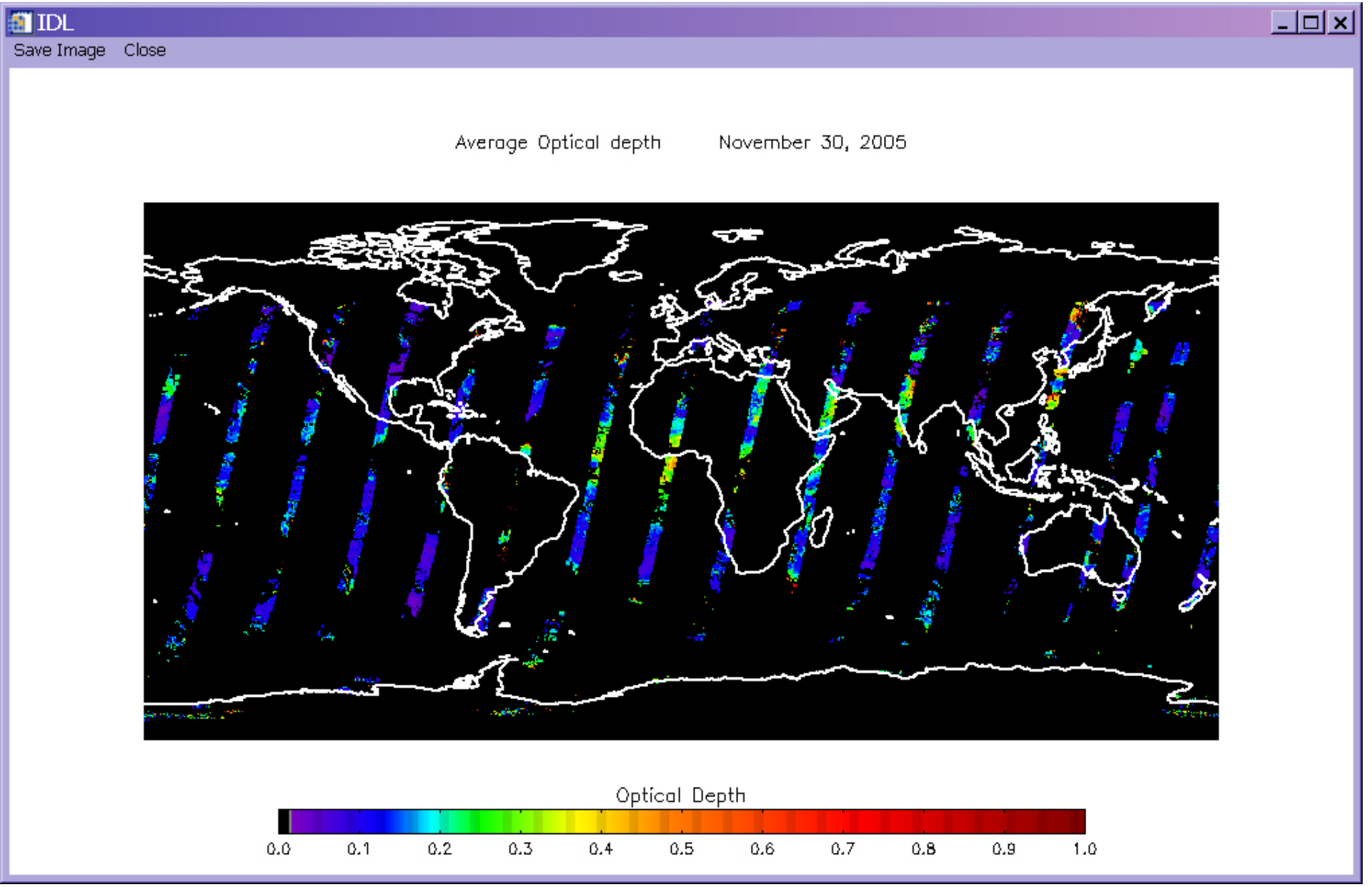
Angular observations (which are not available in MODIS) makes MISR capable of providing additional information on particle size, shape and aerosol height under specific cases

Aerosol Heights from MISR



Smoke Signals from the Alaska and Yukon Fires - July 2004

MISR Level 3 Tool



Level 2 & 3 aerosol

1 file = one orbit - about 98 min Data

17.6x17.6 km^2 , 0.5x0.5, and 1x1deg, daily, monthly, seasonal

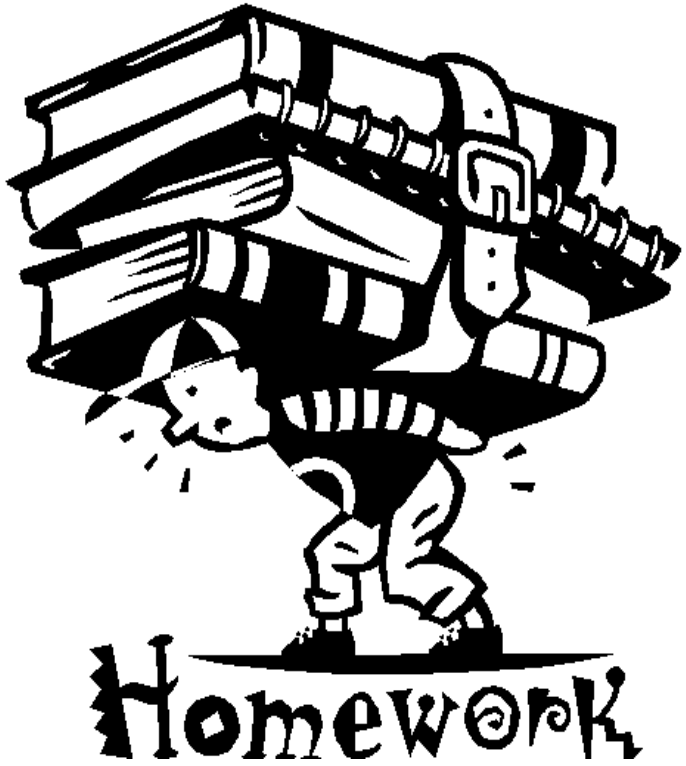
MISR_AM1_AS_AEROSOL_P028_O002510_F12_0022.hdf

RegBestEstimateSpectralOptDepth (AOD – 4 wavelengths)
RegBestEstimateSpectralOptDepthFraction (AOD fraction for small, medium, large, spherical, and non-spherical particles)

Data access and handling tutorial

http://eosweb.larc.nasa.gov/PRODOCS/misr/workshop/ppt/2010_lcluc/misr_tutorial.pdf

Assignment – Week 4



https://docs.google.com/forms/d/1y2HgNJxBCE-N4LQ9UfKvr_SsZgfxca6Fekb8ezTngYQ/viewform

References & links

. ARSET-AQ webpage

http://airquality.gsfc.nasa.gov/index.php?section=11

. MODIS ATMOS

http://modis-atmos.gsfc.nasa.gov/mod04_l2/

. MISR DATA

http://eosweb.larc.nasa.gov/PRODOCS/misr/Quality_Summaries/L2_AS_Products.html

. OMI DATA

http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI

. IDEA

http://www.star.nesdis.noaa.gov/smcd/spb/aq/

. SMOG BLOG

http://alg.umbc.edu/usaq/

For Today's Material click here

http://airquality.gsfc.nasa.gov/IntroWebinar/